BITUMINOUS COAL RESEARCH, INC.
SPONSORED RESEARCH PROGRAM

GAS GENERATOR RESEARCH AND DEVELOPMENT
FLUIDIZED BED GASIFICATION

Progress Report No. 10-A
(BCR Report L-473)

I. INTRODUCTION

This report summarizes progress achieved during the month on the program "Fluidized-bed Gasification" which is a part of the general program, "Gas Generator Research and Development," being conducted by Bituminous Coal Research, Inc., for the Office of Coal Research. This represents the tenth report of progress under Contract No. 14-32-0001-1207.

Design work on the fluidized-bed gasification PEDU (Process and Equipment Development Unit) has begun after receipt, on June 22, 1972, of authorization from OCR to execute a subcontract with Foster Wheeler Corporation for an engineering design package. The laboratory study of the reactivity of HYGAS char with steam has been completed.

A. Fluidized-bed PEDU

During the month of May, proposals were received from four engineering companies offering their services to design the fluidized-bed PEDU. On June 5, 1972, after intensive review of all proposals, authorization was requested from OCR to negotiate a subcontract with the Foster Wheeler Corporation. Authorization was received and Foster Wheeler has begun their preliminary design work.

Representatives of Foster Wheeler met with BCR on June 28 to discuss the basis for design of the PEDU. It was emphasized that the flow diagram given in Kopper's drawing Number 2A438 is only a schematic of the multiple-bed concept and is not to be regarded as a fixed basis for further design. It was intended to develop a multiple fluidized-bed gasification system that could start with coal and have, as the only product, a clean fuel gas. The flow diagram presented in drawing Number 2A438 is one way of accomplishing this. However, the individual pieces of equipment contained in that diagram are meant only to define process functions, not to detail an exclusive or optimum choice of hardware.

The scope of work to be performed by Foster Wheeler was discussed to ensure complete understanding on the part of BCR as well as Foster Wheeler. Foster Wheeler will provide, at a minimum, specifications and drawings in sufficient detail to substantiate costs and to establish performance criteria.

P & I drawings, general arrangement drawings, and details of specialty vessels would be typical of the work to be performed. Piping details or isometrics, structural steel details, and other such "detail design" items are not considered part of this initial design work.

The Pittsburgh seam coal shown in Column C of Table 5 will be used for the base case material balance calculations in an air blown system. Reactor dimensions have not been fixed, but the internal diameter should be at least 14 inches to ensure meaningful data for scale-up purposes. Solids handling and storage vessels and equipment will be designed for semi-continuous operation, that is, a 24- to 48-hour test run.

B. Laboratory Investigations

The study of the reaction of HYGAS char with steam was completed. A gas chromatograph was readied for on-stream analysis of the product gas from the fluidized-bed batch reactor.

1. Char Reactivity Studies: The study of the reaction of HYGAS char with steam was completed. Appendix A in Progress Report 9-A (BCR L-471) gave a description of the experimental procedure. Sixty runs were made at temperatures from 900 to 1100 C and steam concentrations in nitrogen from 33 to 100 percent. As with the other chars investigated, the reaction rate was found to be independent of particle diameter; that is, chemical reaction at the internal surfaces was the rate-controlling step. The experimental data were described by the following rate equation:

$$(1 - x) = \text{Ash} + (1 - \text{Ash})\, e^{-k(C_{H_2O})^{.63}t}$$

and

$$K = 3.31 \times 10^5\, e^{\frac{-1.84 \times 10^4}{T}}$$

where X = fraction of char reacted

T = temperature, °Kelvin

C = concentration of reacting gas

t = time in minutes

k = apparent reactivity $\left(\frac{\text{lb C reacted}}{\text{lb C inventory - min}}\right)$

Ash = weight percent of ash in unreacted char

From this rate equation, an activation energy of 36 kcal/mole and a pre-exponential factor of $3.31 \times 10^5\ \text{min}^{-1}$ were calculated. Again the rate was fractional order, 0.63, with respect to the steam concentration. Table 6 presents the analyses of the chars used in these reactivity tests. Figures 13 and 14 are plots of typical experimental data along with plots of the derived rate equation. Figure 15 is an Arrhenius' plot of the reaction rate coefficient of HYGAS char compared with other chars investigated.

TABLE 5. TYPICAL ANALYSIS OF COALS TO BE USED IN FLUIDIZED BED GASIFICATION PILOT

	A		B		C		D	
	Lignite Sample 1963-8016-12		Subbituminous C, Elkol Sample 2280-8016-9A		High Volatile A Bituminous Pittsburgh Seam Sample 2655-8016-4		Medium Volatile Bituminous Lower Kittanning Seam Sample 2697-8016-6A	
Analyses	As Used	Dry	As Used	Dry	As Used	Dry	As Used	Dry
Proximate, Percent								
Moisture	25.4	--	17.9	--	1.4	--	0.4	--
Volatile Matter	33.7	45.2	34.3	41.8	37.9	38.4	23.0	23.1
Fixed Carbon	32.7	43.8	44.3	54.0	54.5	55.3	61.7	61.9
Ash	8.2	11.0	3.5	4.2	6.2	6.3	14.9	15.0
Ultimate, Percent								
Moisture	25.4	--	17.9	--	1.4	--	0.4	--
Carbon	48.2	64.6	59.2	72.1	78.1	79.2	74.2	74.5
Hydrogen	3.2	4.2	4.3	5.2	5.4	5.5	4.5	4.5
Nitrogen	0.6	0.9	1.1	1.3	1.4	1.4	1.1	1.1
Sulfur	1.1	1.5	0.7	0.9	1.5	1.5	2.4	2.4
Ash	8.2	11.0	3.4	4.2	6.2	6.3	14.9	15.0
Oxygen (by difference)	13.3	17.8	13.4	16.3	6.0	6.1	2.5	2.5
Heating Value, Btu/lb	7,980	10,700	10,250	12,490	13,890	14,090	13,130	13,180

TABLE 6. ANALYSIS OF CHARS USED IN REACTIVITY TESTS

	Dry Basis, Percent								
	Proximate			Ultimate					
	Volatile Matter	Fixed Carbon	Ash	Carbon	Hydrogen	Nitrogen	Sulfur	Ash	Oxygen
FMC	2.85	88.5	7.65	88.7	0.8	1.3	0.6	7.7	0.9
Consol	11.6	58.4	30.0	56.1	1.92	1.16	9.39	30.0	1.43
HYGAS	2.1	74.6	22.5	73.5	1.35	0.62	2.89	22.7	0.0
Lignite*	11.3	71.4	17.3	77.1	1.03	0.49	0.90	17.3	4.18
Elkol*	5.9	82.5	11.6	82.0	1.8	--	0.37	11.6	--
Pittsburgh*	4.2	83.5	12.3	83.4	1.42	0.9	0.76	12.3	1.22

* Char made from these coals in BI-GAS Stage 2 PEDU.

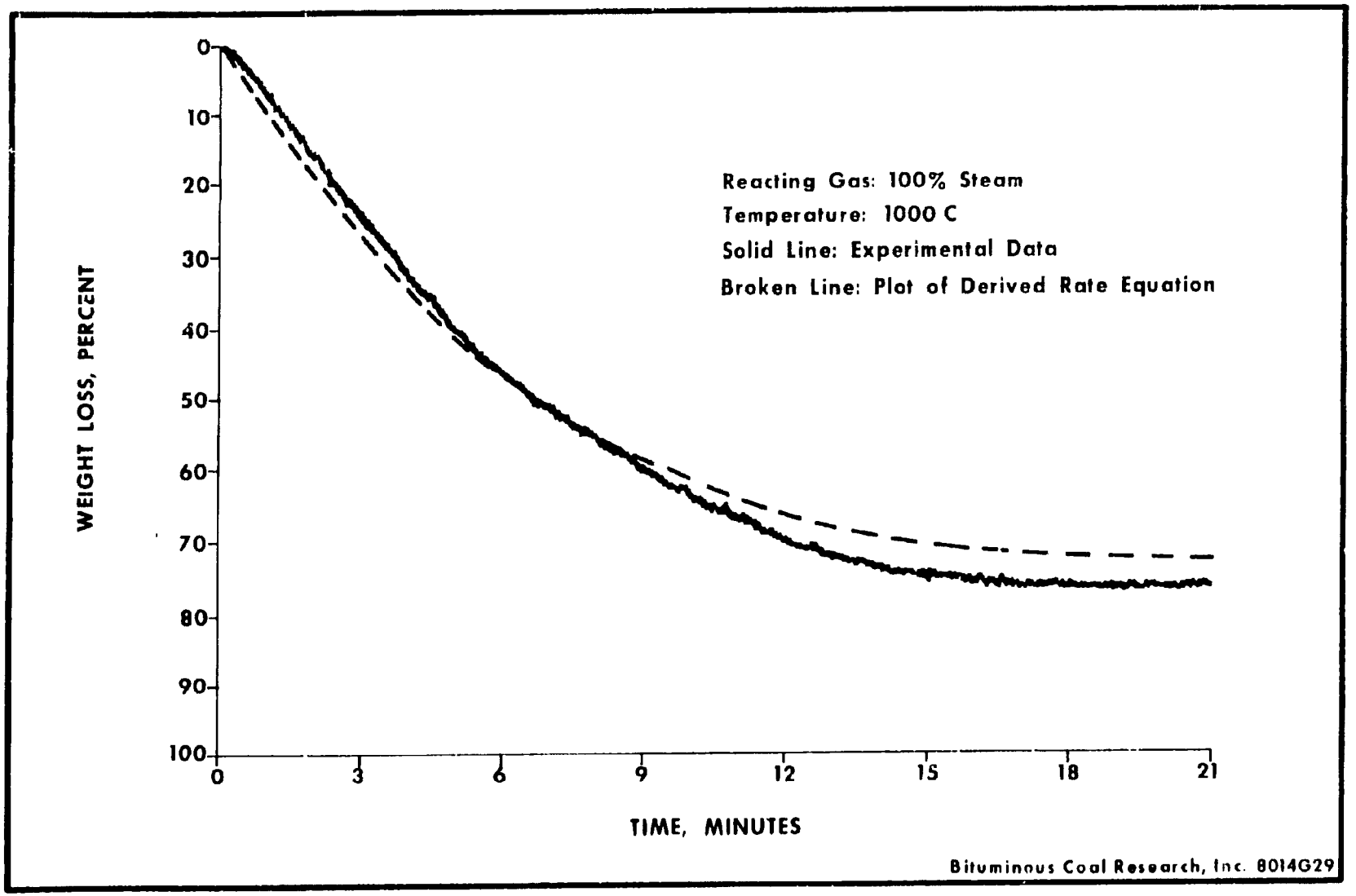

Figure 13. Correlation of HYGAS Char Reactivity Data

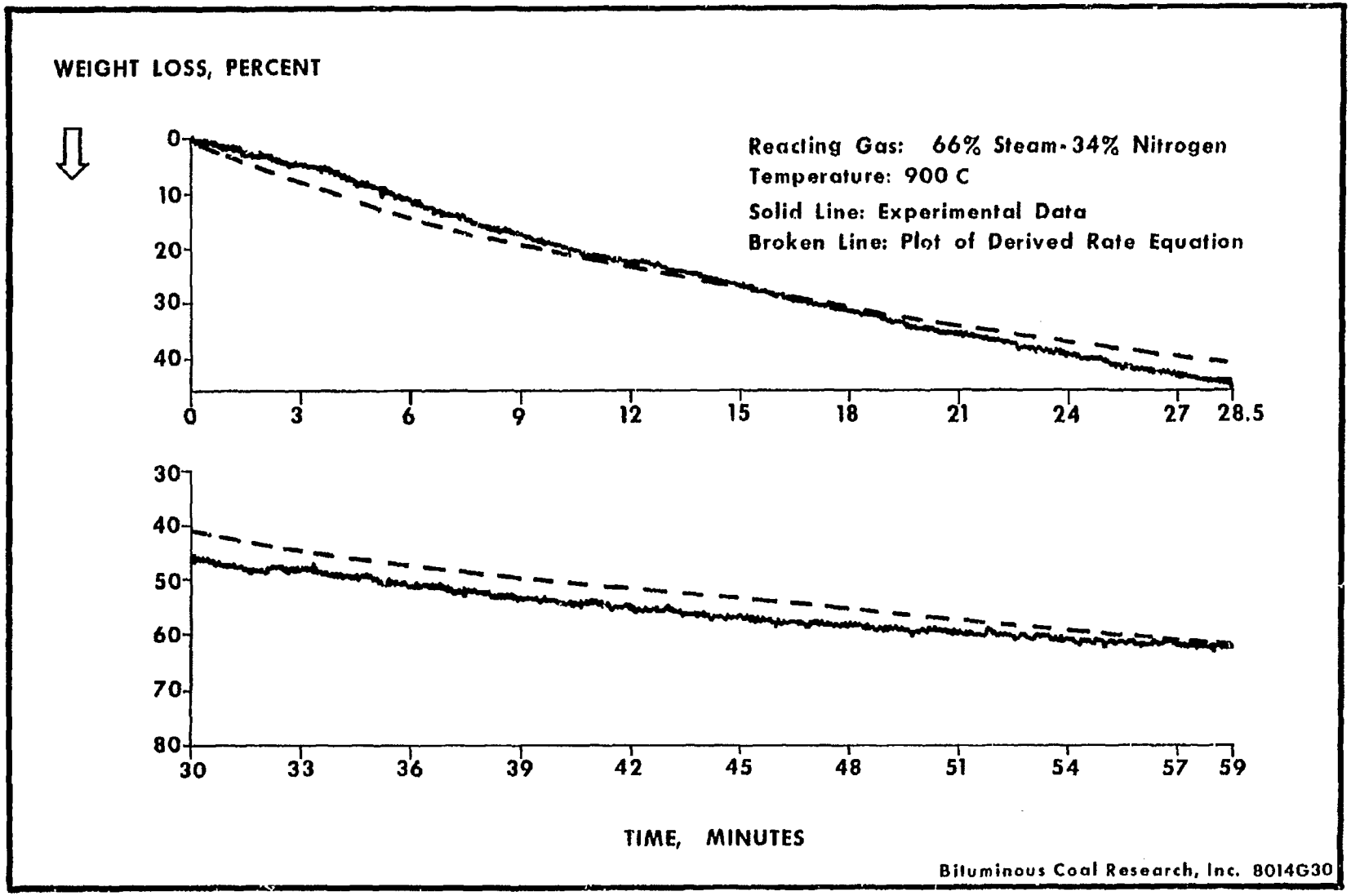

Figure 14. Correlation of HYGAS Char Reactivity Data

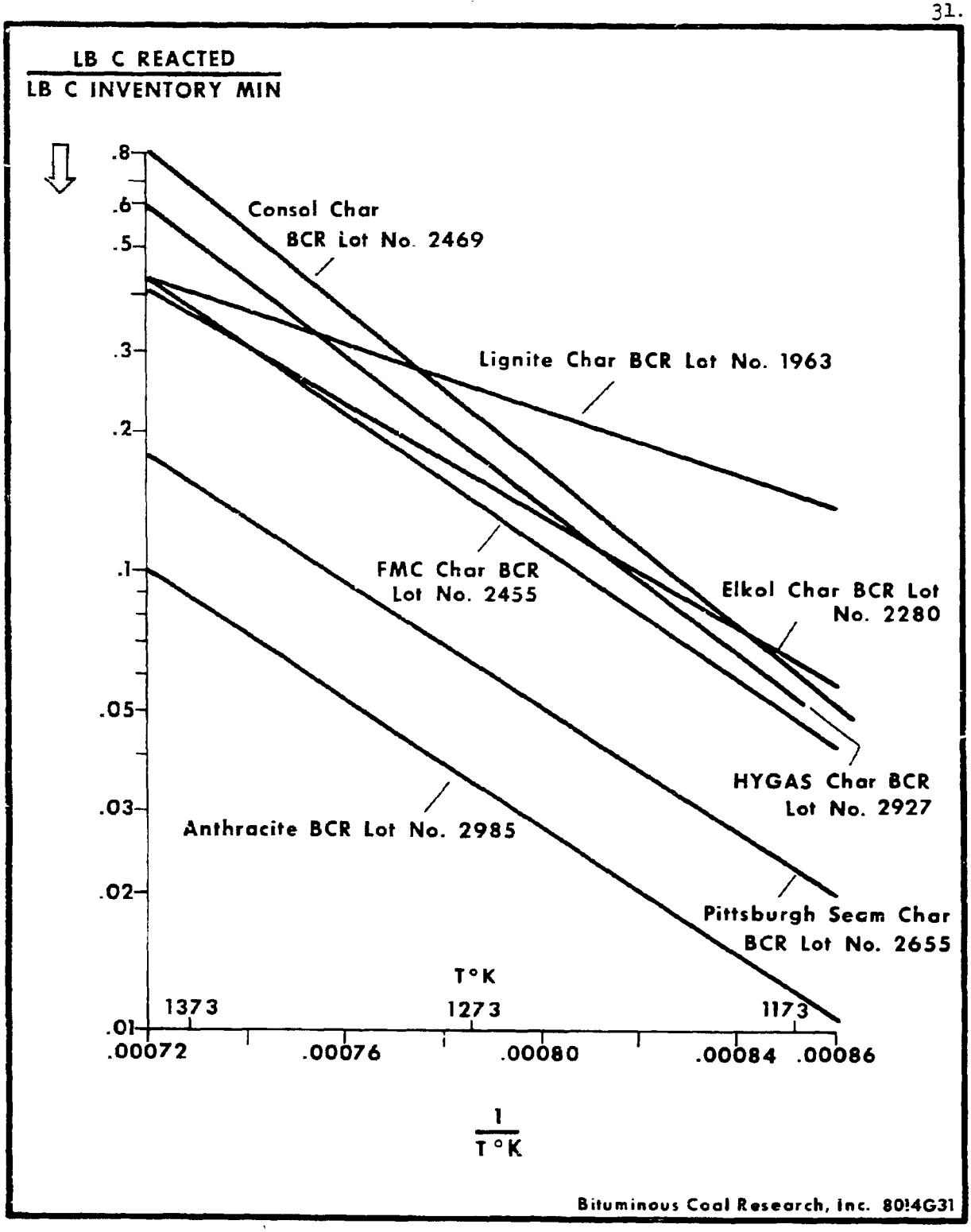

Figure 15. Arrhenius Plot of Char Reactivity Data with Steam

2. Fluidized-bed Gasification Batch Reactor: The fluidized-bed batch reactor work was temporarily halted to allow time for the reinstallation of the F & M gas chromatograph. The chromatograph has been installed and calibrated and will be used during the next report period to substantiate the predicted behavior of the batch reactor. Preliminary work indicates that the reactor kinetics for the oxygen/carbon dioxide gasification study can be described by assuming all the oxygen instantaneously reacts to form carbon monoxide and the subsequent char/carbon dioxide reaction can be described by the rate equations previously established. The extent of carbon dioxide decomposition that can be achieved in a reactor of reasonable volume is yet to be investigated.